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DUBAI SMART MAP, A NEW TOOL ENABLING GEO-DIGITAL GOVERNMENT, DRIVEN BY INNOVATIVE GEOSPATIAL THINKING FOR A SMART AND SUSTAINABLE DUBAI

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ABSTRACT

One cannot deny the remarkable change in Dubai over the past few years. The Emirate expanded and continued to strive towards excellence in urban technologies, setting its pathway to a sustainable development with the advent of digital transformation.

Moreover, the rising popularity of urban solutions utilizing the science of where as a backbone stimulates tremendous research interests in digital twin capabilities mimicking real-time how and where to help people who need it most.

This doesn't only transform how governmental collaboration in Dubai works in tandem at all stages – planning, design, construction, operations, development, outage management and during emergencies but also creates new possibilities for tools giving controlled access to up-to-date urban dynamics information allowing better decision-making.

Therefore, Smart Dubai Map as an initiative where an open platform for the collection, processing and dissemination of multisource big real-time data was implemented, provides decision makers with an up-to-date Base map as well as a unified 3D Map. This paper describes how Smart Dubai Map can help in management of various functions of a smart Dubai; and explores the latest technology tools used within the solution including Machine Learning, 3D Drone and 360° Lidar Scans.

KEYWORDS: Smart City Projects; Dubai sustainability; GIS; Smart Maps; Smart Cities; Urban Development & Research Development

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Original Article

INTRODUCTION

The Emirate of Dubai has experienced a unique and rapid transformation like no other city on Earth. From modest beginnings as a desert city with an estimated population of 10,000 in 1900, it has grown into a mega-city, with a population of over 2.1 million people and more than 10 million annual visitors. Today, Dubai is one of the most cosmopolitan cities in the world, preparing to host the most sustainable world event: Dubai Expo 2020, and focused on transforming into the most sustainable city in the world. For a city to be sustainable, it needs to encompass three main pillars; environmental, economic and social sustainability. The key goal is to provide citizens and residents with the highest quality of life, paired with the lowest environmental footprint.

H.H. Sheikh Mohammed Bin Rashid Al Maktoum, Vice President and Prime Minister of the UAE and Ruler of Dubai set forth his vision to make Dubai the happiest city on earth. To achieve this, Dubai is embracing technology innovation, creating value through smart solutions, creating a culture of government excellence and prioritizing service

levels thereby maximizing happiness. Dubai Municipality, as a key strategic partner, is a critical enabler of this vision.

The Municipality has a key role to play with regards to provide geospatial data and services to the Emirate. In 2001, Dubai Municipality appointed the National Mapping Centre for Dubai under law 6/2001 making the organization responsible for unifying geographic data across the Emirate. The Municipality's GIS Center provides a variety of data services, addressing and geospatial applications to Municipality departments as well as other Dubai government entities. Geographic data is used across Dubai in the public and private sector to inform decision-making and planning. Organizations within the Dubai government that are users of geographic information include the Dubai Land Department, Dubai Police and the Dubai Roads and Transport Authority (RTA). The center is providing a valuable service to the government but recognizes an opportunity to develop further as an organization and a geospatial community. As such, this project will help the center define and achieve a future state for geospatial data and technology within the Emirate to ensure that the entire geospatial community within the Emirate reach their potential and realize the economic, environmental and societal benefits that geospatial information can support.

Many of the traditional challenges faced by Dubai Municipality, including urban planning, safety and security, sustainable development and environmental protection require accurate geospatial information that is readily available to those that need it, when they need it. A resilient geospatial infrastructure and reliable geospatial data also supports the delivery of new technologies and their application, such as smart cities, the GIS of Things (GoT) and 5G. Accordingly, Smart Dubai Map was successfully implemented as an application of GIS to sustainability projects in Dubai Emirate, it guides decision makers and government entities better understand their needs, map their work and initiatives, measure the impact, analyze related performance and engage stakeholders within future sustainability programs. In fact, Smart Dubai Map Initiative is an open platform for the collection, combination, and distribution of large numbers of the Emirate's real-time data along with up to date 2D and 3D geospatial information, allowing multiple entities and departments to scientifically plan, execute, and report on sustainable development relevant to Dubai programs.

MATERIALS AND METHODS

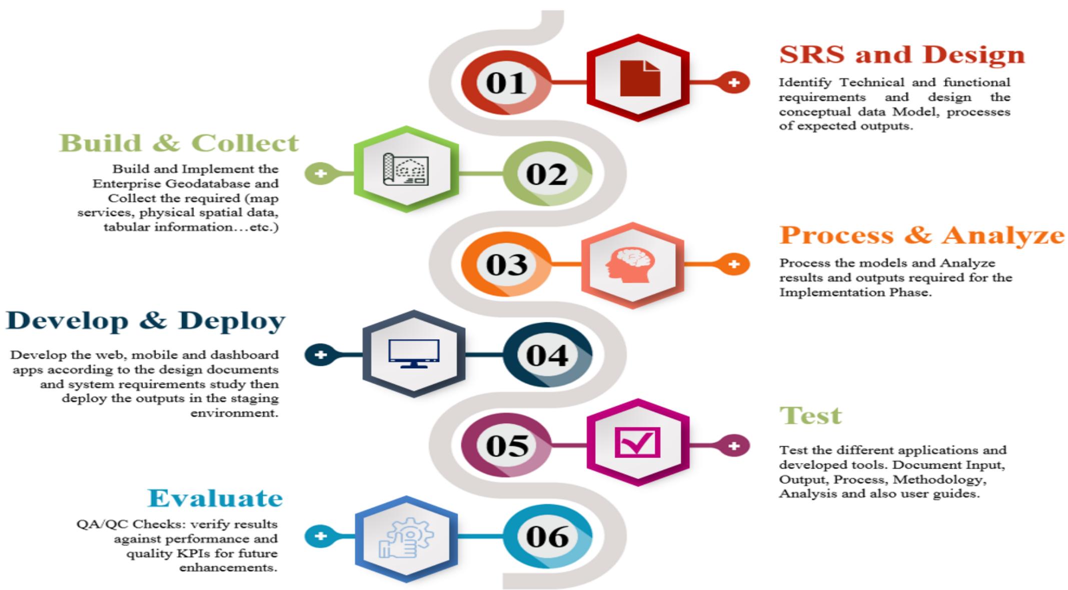

Figure 1: SDM Development WorkFlow.

Smart Dubai Map (SDM) is an enterprise GIS Solution comprised of web, mobile and dashboard apps providing next generation spatial features with 2D and 3D data. It is disseminating different datasets that are important for city planning and development organized by themes including urban planning, public works, utilities and transportation. The solution's features range from geo-assets, geo-environment, and spatial analytics for planning, design and operations. Figure 1 describes the methodology workflow adopted to implement the enterprise GIS Smart Dubai Map. The first step of this workflow is the identification of technical and functional requirements reported as a System Requirement Study Document. This document identifies the data and functional requirements for all of the intended solution components based on a comprehensive research about the gaps in actual scenarios of Dubai smart mapping.

Data modeling is an essential step in the process of creating any enterprise solution. It helps to understand the domain and organize work accordingly. Therefore, a scalable data model was designed to be easy to adjust without affecting the developed solution. It was designed using UML2.0 Standard. Figure 2 shows an example of transportation class diagram:

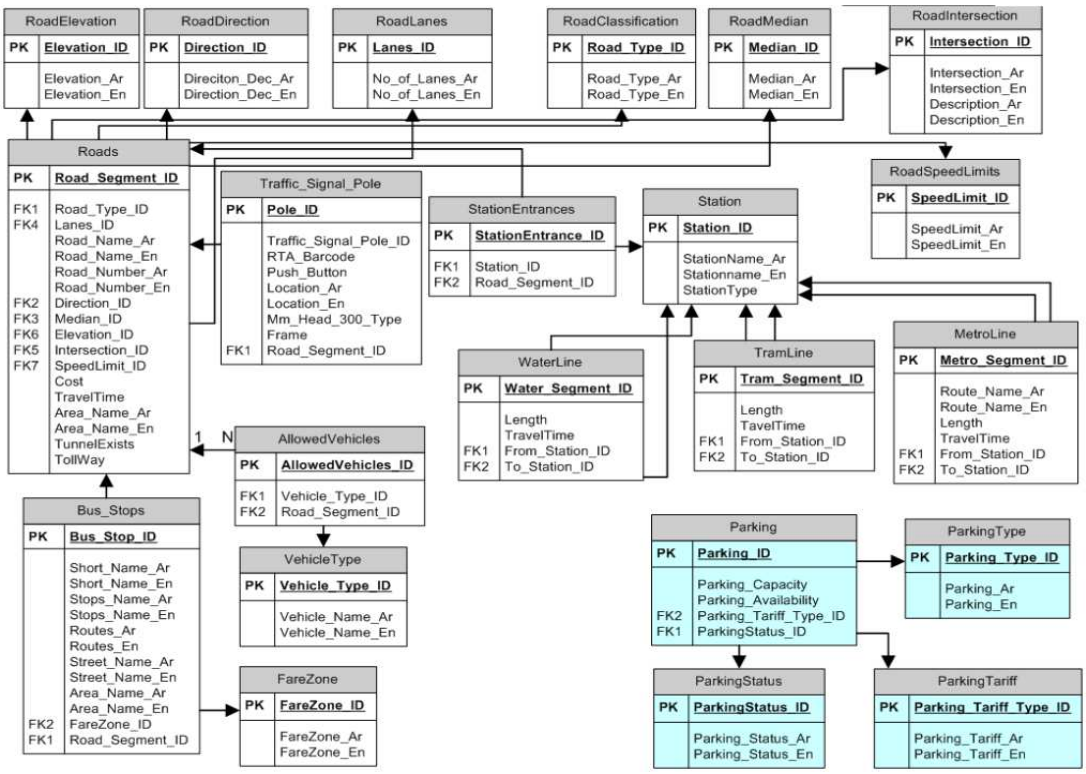

Figure 2: Transportation Class Diagram.

The third step was the most challenging of all (Data Collection), many reasons behind these challenges are:

- Required conversion of paper maps to spatial data is a long manual process.
- Non conformity of spatial datasets in terms of spatial reference, extent and positional accuracy.
- Missing information/ attribute data in several datasets.
- Missing metadata in 90% of available spatial datasets.
- Access Rights to some datasets took very long time to be granted.
- Options to share high resolution multi date satellite images are very limited.
- Not available information for many areas to support evaluation and validation processes.

The analysis and processing are two steps where ETL-Extract, Transform and Load, was used, automated workbenches had been developed to geo reference, adjust, load and update datasets from different data sources.

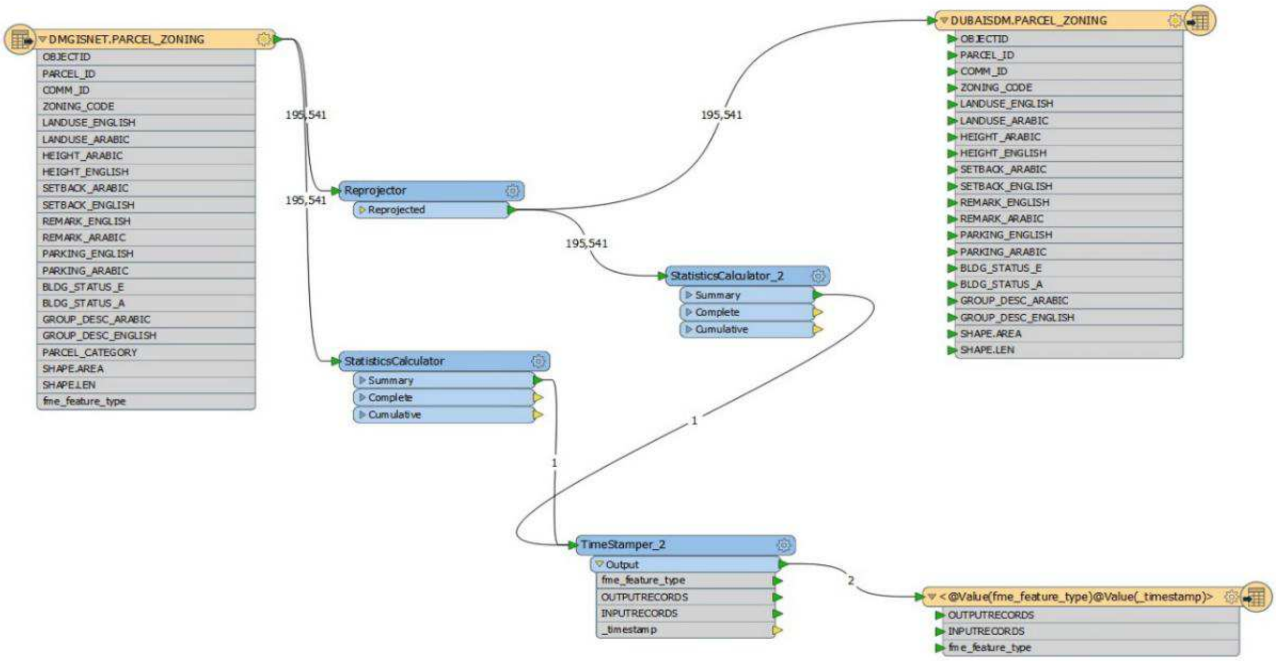

Figure 2: Example of FME Workbench Transforming Parcel Zoning to SDM.

The development phase involved multiple platforms, since SDM has multiple components web, mobile and dashboard. The development phase is a continuous process along with testing until the results are validated against users' expectations and technology updates.

Data Description

SDM requires different types of inputs: raster, vector and alphanumeric managed by shared desktop-GIS, web-GIS and Mobile-GIS environments. Mainly, the solution combines data from satellite platforms, field data collection outputs including street mapping, drone imagery and live inspections along with administrative records fed to the solution enterprise geo database through data links and real time web-services.

Figure 4 lists some of the main data sources that are very helpful to interpret, analyze and visualize results. Especially, land use vector layers with information about plots demarcation, urban centers, and locations of assets in the Emirate. The GIS Center provided sensitive information about boreholes and reports relevant to soil types in order to study and interpret some variance parameters between soil information and groundwater quality for environmental initiatives. Other Layers are used for navigation purposes, such as Landmarks, Points of Interest, Network Dataset, Makani Entrances, Zoning, Communities, Major Projects, etc.

Since Base maps are necessary for the SDM Web and Mobile components, English and Arabic Base maps had been requested and granted to be used from the Dubai Spatial Data Infrastructure Committee.

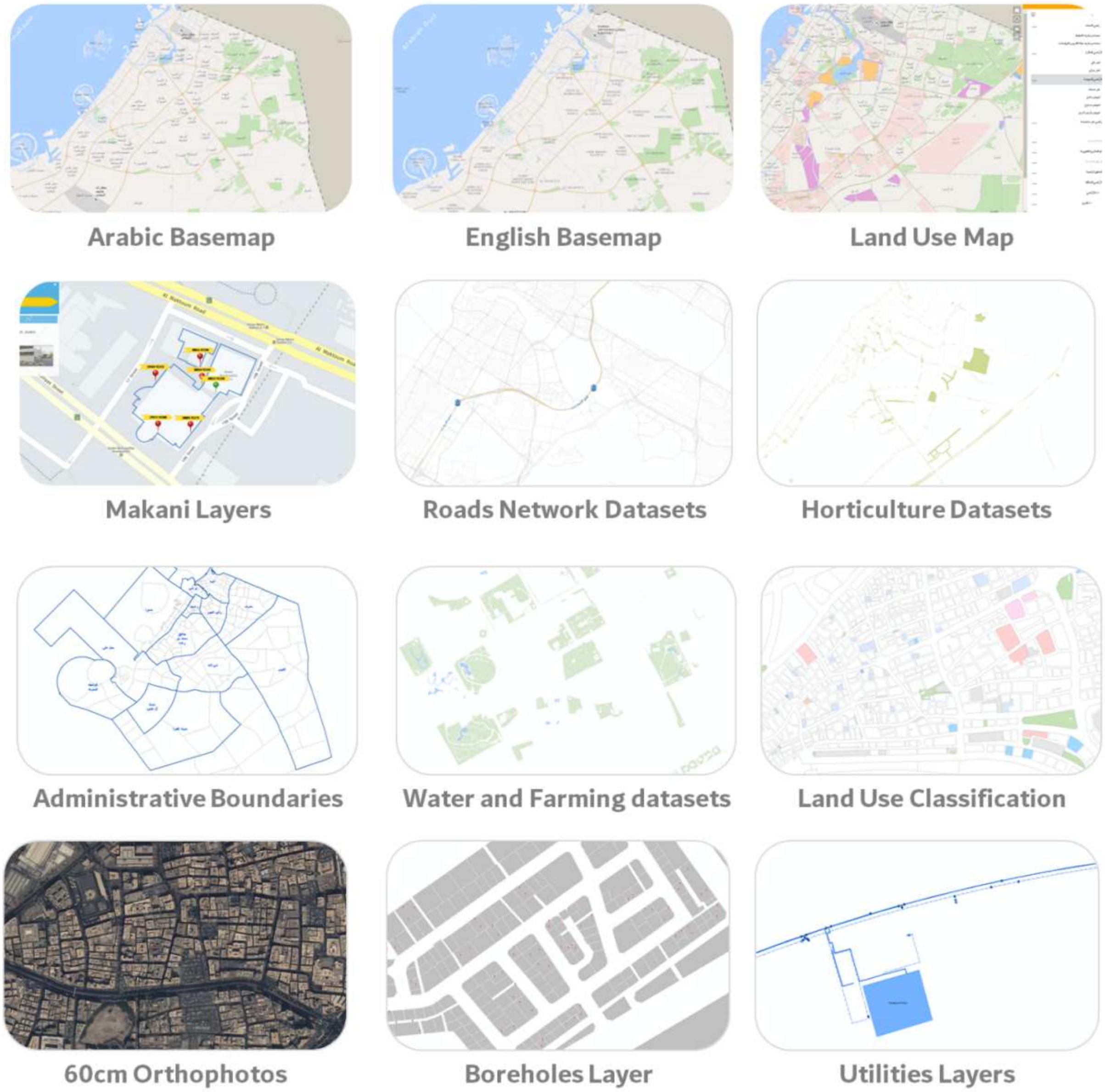

Figure 3: Some of the Main Datasets available through SDM.

Street Mapper: 3600 Lidar Vehicle

The GeoDubai street mapper as one of the SDM inputs is an integrated solution for the collection of geospatial information and 3D mapping, combining the latest sophisticated scanning devices with easy-to-use field software and efficient office software, which is one of the most important inputs of geomagnetic intelligence.

The system consists of a high-resolution laser scanner, GPS devices and 360-degree panoramic cameras. It is installed on the roof of GeoDubai vehicle with a four-wheel drive and then collected data in 3D dense point clouds with accurate coordinates and panoramic images, while driving at the same speed of the road, then the data is processed in an office to create integrated data for the 3D city.

The use of this system greatly improves the accuracy, speed and safety of data collection processes on highways and also avoids the closure of streets and areas that could be caused by traditional ways of collecting geospatial information.

The GeoDubai Street Mapper feeds the SDM with multiple critical datasets such as 3D buildings, road assets, cross sections of roads and infrastructure and 3D elevation models.

Figure 4: GeoDubai Lidar Field Collection Vehicle.

Drone Imagery

The 3D drone surveying and mapping service available at GIS Center of Dubai Municipality, uses the unmanned aircraft to conduct accurate aerial photography with the aim of creating accurate maps, facilitating immediate and continuous update of the comprehensive and unified Base map of Dubai. SDM is using the drone processing results as imagery and 3D data layers for visualization and analysis.

Figure 5: GeoDubai Drone Mapping used by SDM.

Administrative Datasets

Given, the significance of the coordinated effort between Dubai Governments to collect and share data related to sustainable development in the Emirate, the task of establishing an integrated solution for visualizing existing and predicting sustainability parameters interactions is quite interesting and important. In fact, GeoDubai established a clear agenda for the implementation of necessary framework of policies, partnerships, standards, data, procedures, technology

and institutional capabilities that collectively comprise the Dubai Spatial Data Infrastructure which is actually the main data source for this research enabling access to more than 600 spatial data layers supporting the research results.

The datasets used through GeoDubai SDI are organized in the following themes:

- Urban Planning
- Utilities and Telecom
- Transportation
- Oil, Gas, and Energy
- Safety and Security
- Whole of Government
- Natural and Cultural Heritage
- Public Health
- Businesses
- Social Services
- Education
- Information Services

Figure 7 describes the main Dubai government entities contributing to update the geospatial datasets used within SDM product.

Figure 6: Main Government Bodies Contributing to SDM Database Model.

Metadata

Standards are fundamental to the successful implementation of SDM as a platform referencing spatial data from different sources. They ensure data is harmonized and interoperable, make data more easily discoverable and accessible, optimize operational processes and improve data quality.

The GIS center has established and adopted best practice standards and compliance mechanisms that enable legal, data, semantic and technical interoperability which are fundamental to deliver integrated geospatial information and knowledge creation. Accordingly, the ISO 19115 was the metadata standard adopted to manage the SDM metadata. It contains a data dictionary of hundreds of metadata elements and sub-elements, covering:

- Identification of the data, including the geospatial and temporal extent, when the data was published and revised, how to cite the dataset, and contact details for the steward & other stakeholders.
- Constraints on accessing and/or using the data.
- Lineage – how the data was acquired and prepared.
- Maintenance – how the steward maintains (or plans to maintain) the data.
- Quality metadata – the results of assessing the data quality.
- Spatial representation information – for example, is it coverage or vector data?
- Reference system information.
- Content information.
- Portrayal information.
- Distribution information.
- The application schema of the data.
- Metadata about the metadata – who created it, when was it updated.

The SDM is also using the existing mappings from ISO 19115:2014 to the smaller metadata vocabularies which are becoming common in web systems, W3C's Data Catalog Vocabulary (DCAT) and the independent standard Schema. organ emerging best practice chosen to manage the SDM's metadata using a rich subset of ISO 19115, and published in various ways.

Cartography

The visualization of the Base map includes the recently completed national cartographic and symbology standards created by the GIS Center for SDM. This project has created an updated set of common symbology, libraries and standards for Dubai based on international standards and best practices. This has been predominantly focused on online and 'smart' visualizations such as Smart Dubai Map, but plans are in place to extend this as a service to other organizations, including RTA and others.

Machine Learning and Artificial Intelligence Implementation in SDM

Location intelligence powered by GIS technology, magnified by machine learning automation, and done at scale in real time is helping to transform decision making processes. Accordingly, SDM is using advanced geoprocessing scripts and algorithms on geo referenced drone and satellite imagery to automate fieldwork, model growth scenarios, predict crop yields, and assess crop health in real time. And this makes SDM the first implementation in Dubai to extract geospatial data using artificial intelligence and deep learning technologies from high resolution satellite imagery.

If a vegetation cover is neglected, as when the property is foreclosed, it often turns a brown color and impacts the value of oxygen production in the community. The environment and agriculture set of indicators, have made the detection of these neglected green areas of importance for Dubai Municipality.

The department of agriculture, for instance needs a simple solution that helps them to locate neglected green areas from imagery and then use this intelligence to drive field activity and mitigation efforts.

There's a golden rule of deep learning: "The more training data you give, the better the results". Deep learning models become more powerful more and more accurate when fed big data to learn from. To build the first SDM model, the parameters of a healthy vegetation cover were entered, then was trained with multiple imagery data sources.

As a started, the existing vegetation cover dataset was not accurate enough and not up to date, therefore the existing 2018 aerial imagery was used to capture vegetation bodies within urban areas of Dubai and ArcGIS Pro made this process fast and accurate.

Within the same product of ArcGIS Pro, aerial, satellite and drone imagery was stored and managed once collected from the data section of the GIS Center at Dubai Municipality; advanced GIS functionality was used to manage this imagery, including tools for reviewing datasets to manage its quality. Arc GIS Pro's geo processing tools allowed us to create buffers and bounding boxes around labeled vegetation cover locations, and it includes the Export Training Data for Deep Learning tool, which creates the labeled image chips like the ones SDM model needed.

The captured aerial imagery included bands other than just the visible spectrum, and several band configurations were experimented to find the best imagery for the model. Actually, the visible spectrum (RGB), was not enough accurate at identifying vegetation. However, Normalized Difference Vegetation index (NDVI) which measures the difference between red and near-infrared bands gave quite acceptable test results and it was the chosen option for the model as input of training samples. This index takes advantage of the contrast of the characteristics of two bands from a multispectral raster dataset; the chlorophyll pigment absorptions in the red band and the high reflectivity of plant materials in the near-infrared (NIR) band. The documented and default NDVI equation is as follows:

$$NDVI = ((IR - R)/ (IR + R)) \tag{1}$$

As classification criteria, a threshold of NDVI greater than 0.2 was set. This threshold was empirically derived from matching Planet's imagery with the vegetation shape file available at the GIS Center. Any pixel with a value above this threshold is considered "green" or covered by vegetation. With that, the vegetation cover percentage was calculated. This threshold was determined empirically by comparing different resulting masks with the vegetation coverage map provided by the data section. The model outputs values between−1.0 and 1.0, mostly representing greenness, where any negative values are mainly generated from clouds, water; and values near zero are mainly generated from rock and bare soil. Very low values (0.1 and below) of NDVI correspond to barren areas of rock, or sand. Moderate values (0.2 to 0.3) represent moderate plantation and grassland, while high values (0.6 to 0.8) indicate dense green areas. With a single click, the Mode flow Map generates a representation of this index and compares it with cadastral information available in the spatial database.

Figure 7: NDVI Generation using False Color Composite (October 2018).

Thanks to the multi date imagery provided by SkySAT, the tool allows also to observe temporal evolution of irrigation activity with very high resolution up to 60 cm only.

Table 1: Overall Vegetation Cover in October 2018

Area	Vegetation Cover (%)
Dubai (Mean Average)	3.10
All districts (Mean Average)	6.60
All Districts (Standard Deviation)	8.32

System Architecture Design

IT architecture is the process of development of methodical IT specifications, models and guidelines, using a variety of IT notations within a coherent IT architecture framework, following formal and informal IT solution, enterprise, and infrastructure architecture processes. The architecture used to deploy SDM is very stable with minor updates and issues being resolved as and when they occur. There are four main database environments which host the databases and application servers of SDM. The four environments are listed below and the software and versions in operation within each are represented in figure 9:

- Development
- Staging
- Production
- Disaster Recovery

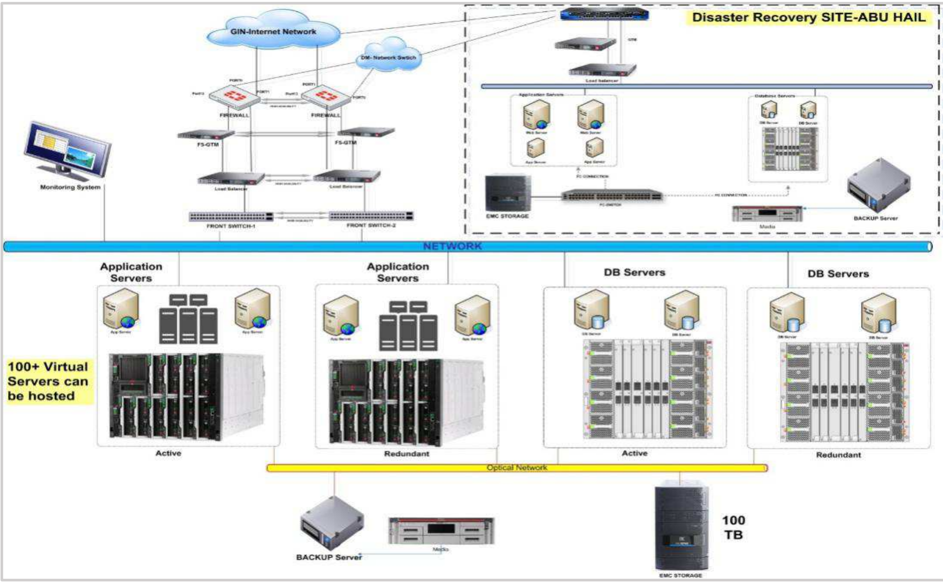

Figure 8: SDM System Architecture.

The production tier is where the SDM database servers are hosted and where most stakeholders interact within SDM and the data. The production environment is a virtualized clustered environment consisting of four main databases:

Intranet Update – This is a restricted access database within the Government Internal Network (GIN) and provides access to SDM data to all Dubai Government web services that are updating the SDM data e.g. Survey Department and Planning Department.

Intranet Publish – This is a restricted access database within the GIN which contains all of the data that is published to SDM.

Internet – This is public facing database which provides access to SDM data that is updated by users outside of the GIN, such as contractors that are undertaking specific projects such as utility networks updates. This database also has publishing capabilities.

Raster – This database stores all of the raster data and accessible by both GIN user and the public.

Once edits within these databases have been finalized, there are a series of processes that control versioning, resolve database conflicts and conduct logical QC check on the data. Once complete, the data is published overnight.

The SDM infrastructure is considered to be relatively resilient and elements of ISO 22301:2012 – Societal security – Business continuity management systems are in place. The published infrastructure availability KPI is 99.9% with availability 24/7. The recovery time objectives are also published and are linked to stakeholder requirements.

Access and Security

Security and access is managed by the databases. There are many different layers within the SDM databases and security is managed at the feature level and the GIS Data Section creates the data access policy for each SDM owner feature class. Any new user who needs access is required to apply online through GeoDubai Portal for data access. This application is evaluated based on the data access policy. Once access is approved by all relevant parties, a new user and login is created and the user is informed that access have been provided electronically.

Solution Components

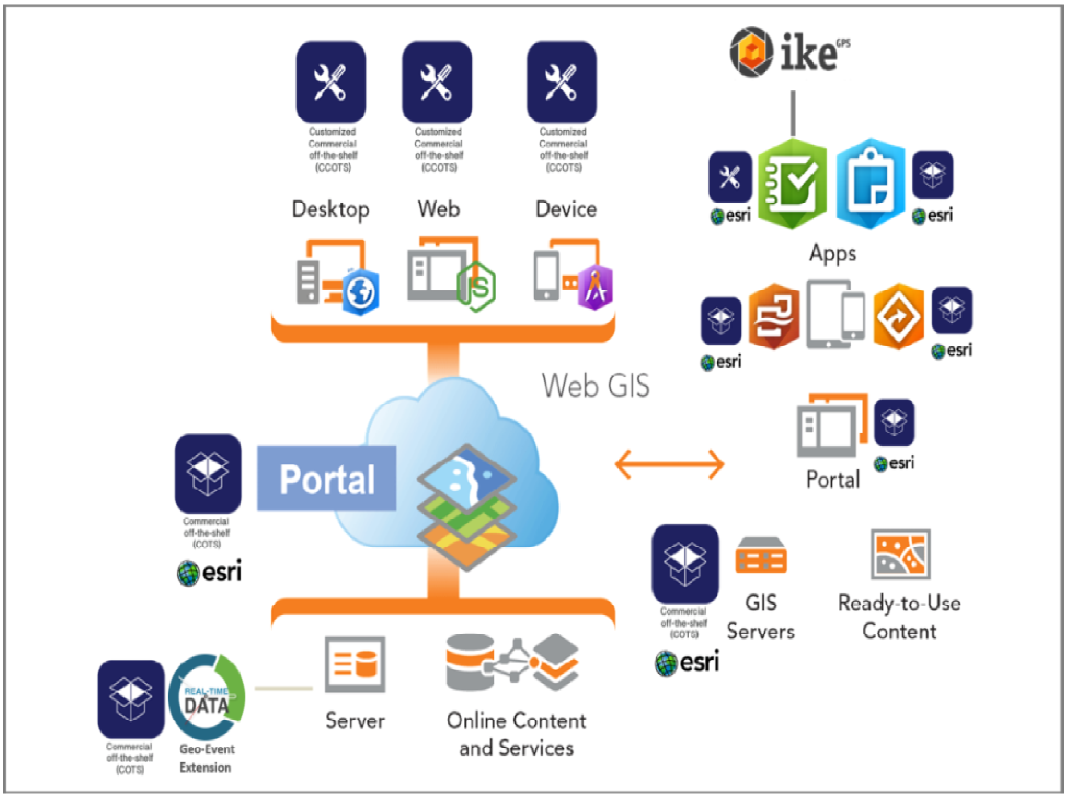

Figure 9: SDM Components.

The modules of SDM were customized using different frameworks based on the latest technology update in the GIS field and specifically in Esri platforms since it is the most reliable and predominant GIS solution provider in the Middle East. The desktop module was customized using Python scripts, while the web module was mainly developed using Arc GIS API for Java script and Arc GIS REST API, and the mobile modules were customized using QT code for cross platform mobile development and HTML 5 for user interface and user experience.

RESULTS

SDM initiative integrates Artificial Intelligence techniques into the GIS to form an enterprise GIS decision support system. This includes machine learning and deep learning algorithms that automate object detection, classification and extraction through Lidar 360° vehicles field data collection transformed to high resolution 2D and 3D vector datasets delivering a highly accurate model that can facilitate deeper analysis and predict precise outcomes, at minimal cost.

A primary goal of this initiative is to apply the latest research in deep learning and GIS to help various government authorities to work in tandem and collaboratively at all stages – planning, design, engineering, construction, asset management, operations and development, managing outage situations and during emergencies; it also aims to develop new technology features to capture the existing Dubai on the ground and underground assets predict Dubai's future challenges, be it to update spatial data records and to assist Dubai's sustainability drives. The SDM solution includes a host of capabilities – smart mapping, big spatial data analysis, collaboration, and field mobility to support achieve these goals.

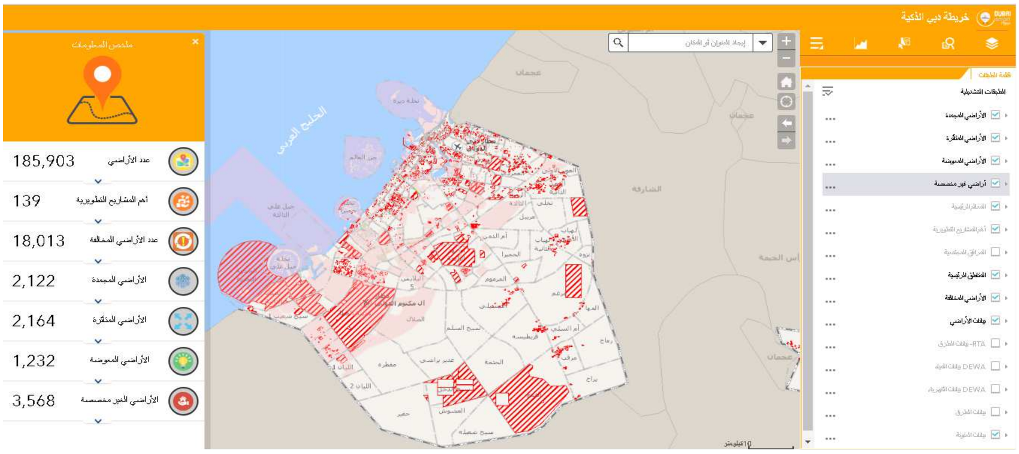

Figure 10: SDM Map Viewer and List of Layers.

SDM Map viewer is a powerful thematic mapping and spatial analysis tool that allows to easily disseminate real time data as maps, graphs, charts and tables. It supports to visualise and analyse the geographic distribution of patterns relevant to different topics such as urban planning, transportation, environment and much more.

Figure 11: SDM Advanced Charts and Toolsets.

The spatial imaging system used for field data collection at the GIS Centre combines high resolution laser scanning and panoramic cameras with precise positioning to get geo-referenced point clouds and images for a wide range of requirements.

The Smart Dubai Map is using the output of this system and rapidly extract and analyse the raw data to turn it into useful geospatial intelligence.

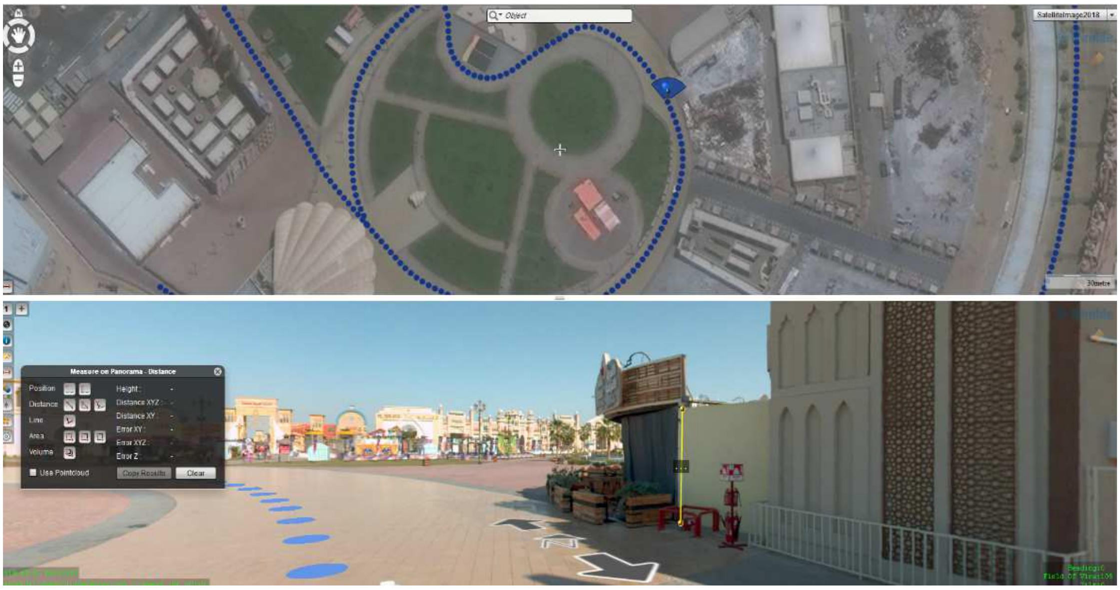

Figure 12: SDM 3600 Panorama and Point Cloud viewer.

Smart Dubai Map mobile component extends GIS beyond the offices of local departments and allows Dubai governmental organizations to make accurate, real-time business decisions and collaborate in both field and office environments. It enables them to decrease task redundancy and keep data more current.

Figure 13: Mobile App for Decision Makers–Projects Follow Up.

SDM Metadata system serves a variety of purposes, it supports effective cataloguing, which includes identifying spatial data records, defining them by criteria, bringing similar datasets together and distinguishing among those that are dissimilar based on themes classification.

It also facilitates interoperability and integrating datasets from different sources. It helps to describe datasets which enable its understanding by all types of users including non-governmental organizations. This permits the most effective levels of interoperability, and how data is exchanged among many systems willing to integrate with Smart Dubai Map Platform.

SDM Metadata system also facilitates digital identification via standard numbers that uniquely identify the spatial datasets the metadata defines. It shares also statistics on the usage of datasets along with the adopted data policy to access each dataset.

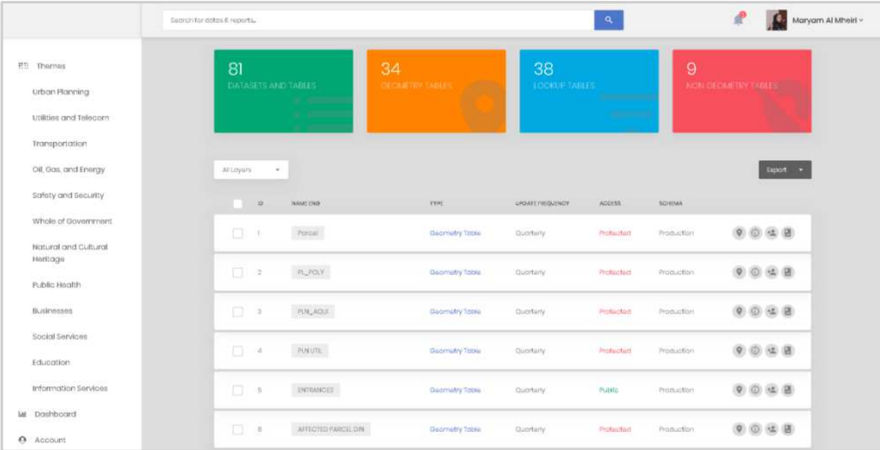

Figure 14: Smart Dubai Map Metadata System.

The SDM 3D Map viewer supports visualizing huge, interactive and immersive urban environments in different areas of Dubai. The results can be on real-world GIS data or fictional plan of the past, present, and future for better decision making.

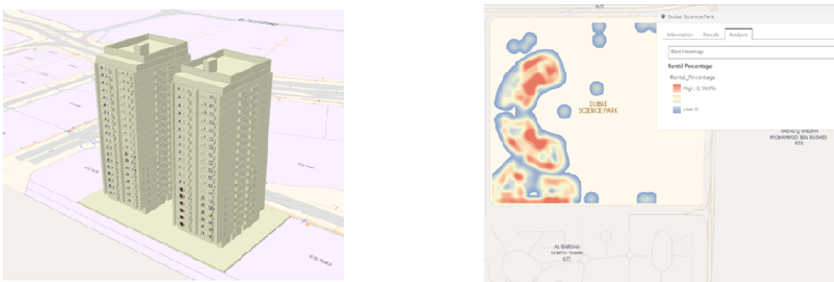

Figure 15: SDM 3D Map Viewer.

Visual inspection of an image is often a good approach, but there's a lot of information in remotely sensed data that is challenging to detect. In fact, green vegetation strongly reflects light in the Near Infra-Red (NIR) spectrum which is invisible to the human eye. The Smart Dubai Map Viewer uses the satellite imagery with 4 bands as explained in the methodology to detect this type of energy and give valuable information through techniques of artificial intelligence and deep learning. The example in figure 17 shows the vegetation health generated by the deep learning module and disseminated through SDM map viewer in Al Kifaf Area.

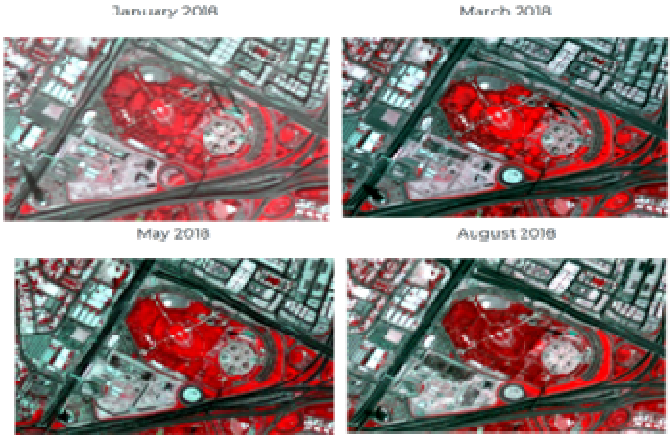

Figure 16: AI Module Results Comparison–AL Kifaf Area.

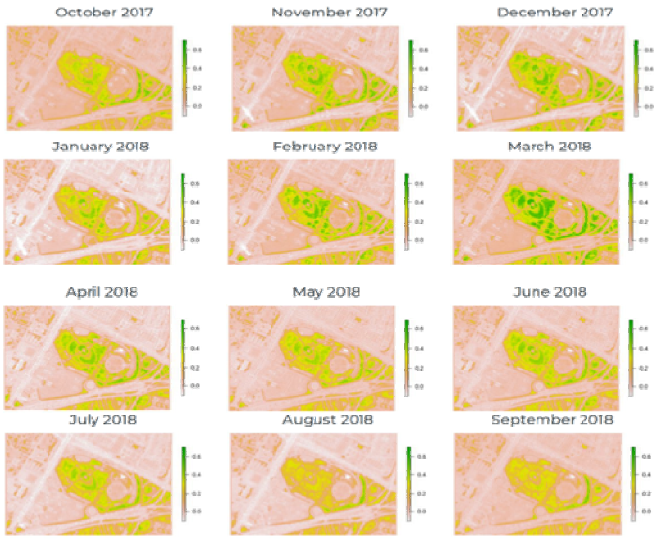

Figure 17: Vegetation health (NDVI) in Al Kifaf over 12 months from October 2017 to September 2018.

CONCLUSIONS

The success of planners in combating chronic urban problems is largely determined by their ability to utilize effective tools and planning support systems that allow them to make informed decisions based on actionable intelligence.

The innovative approach of SDM is reflected in reaching the goal of creating liveable “smart” Dubai and improving the overall quality of life while protecting environment and promoting economic development. It provides the necessary planning platform for visualization, modelling, analysis and collaboration.

It is actually used by authorities’ decision-makers as the main tool supporting the strategic directions for co-defining urbanization parameters, and the spatial planning that promote integrated land use and mobility and facilitate competent urban form, liveability, connectivity, sustainability and economic competitiveness.

The contributions, stakeholders and parties involved in the implementation and design of SDM also acknowledged that such solution constitutes the backbone for long term collaboration between key governmental bodies for sustainable economic development (tourism, trade, retail, business and finance).

There are many advantages of using SDM, including business intelligence that allows creating and maintaining volumes of spatial data relevant to Dubai's main projects in a way that makes the SDM master data complete, accurate, consistent, and contextual for smooth functioning of all organizations involved.

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